

Ultrafast X-ray Measurements at the Sub-Picosecond Pulse Source (SPPS)

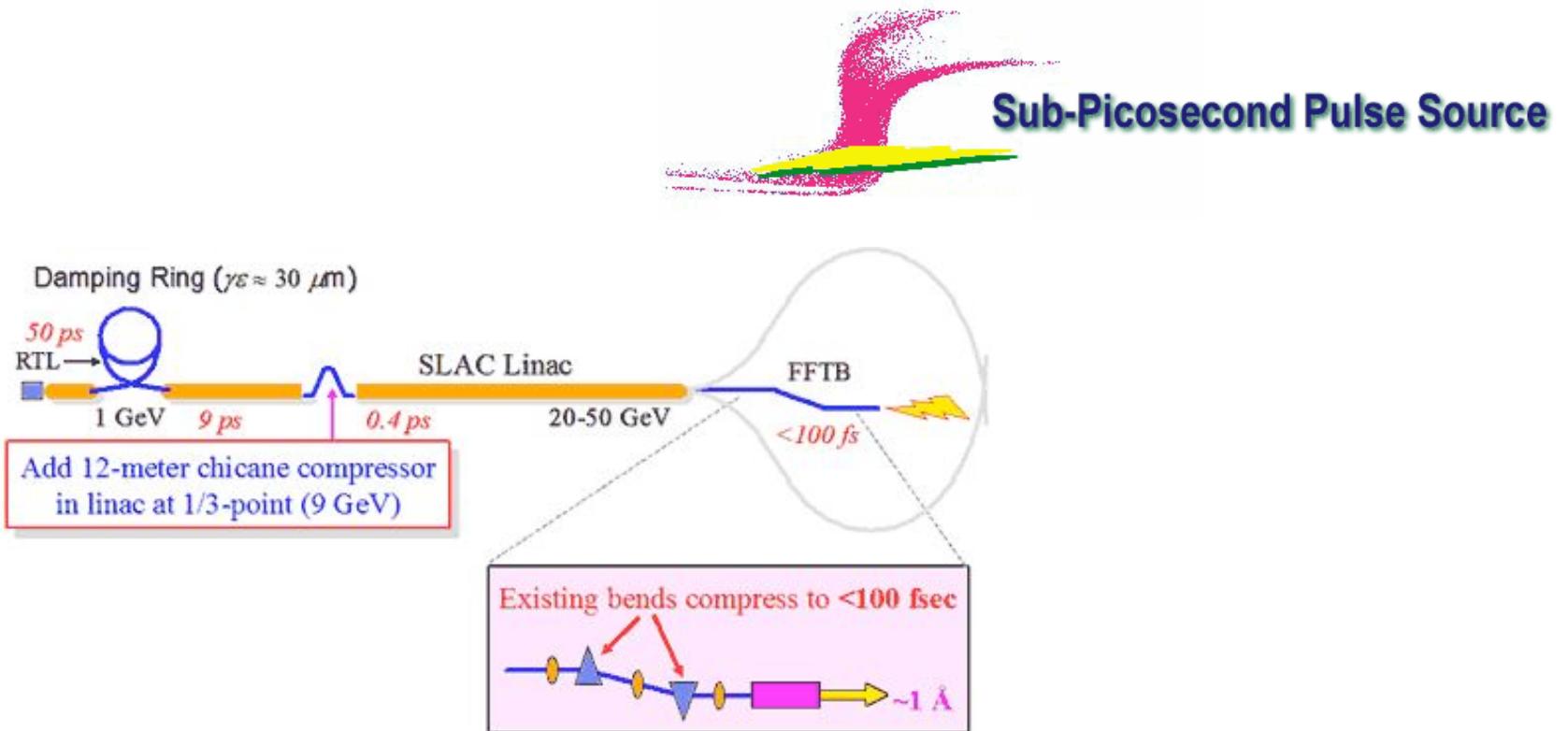
Aaron Lindenberg
SLAC

2004 Workshop on Ultrafast X-ray Science

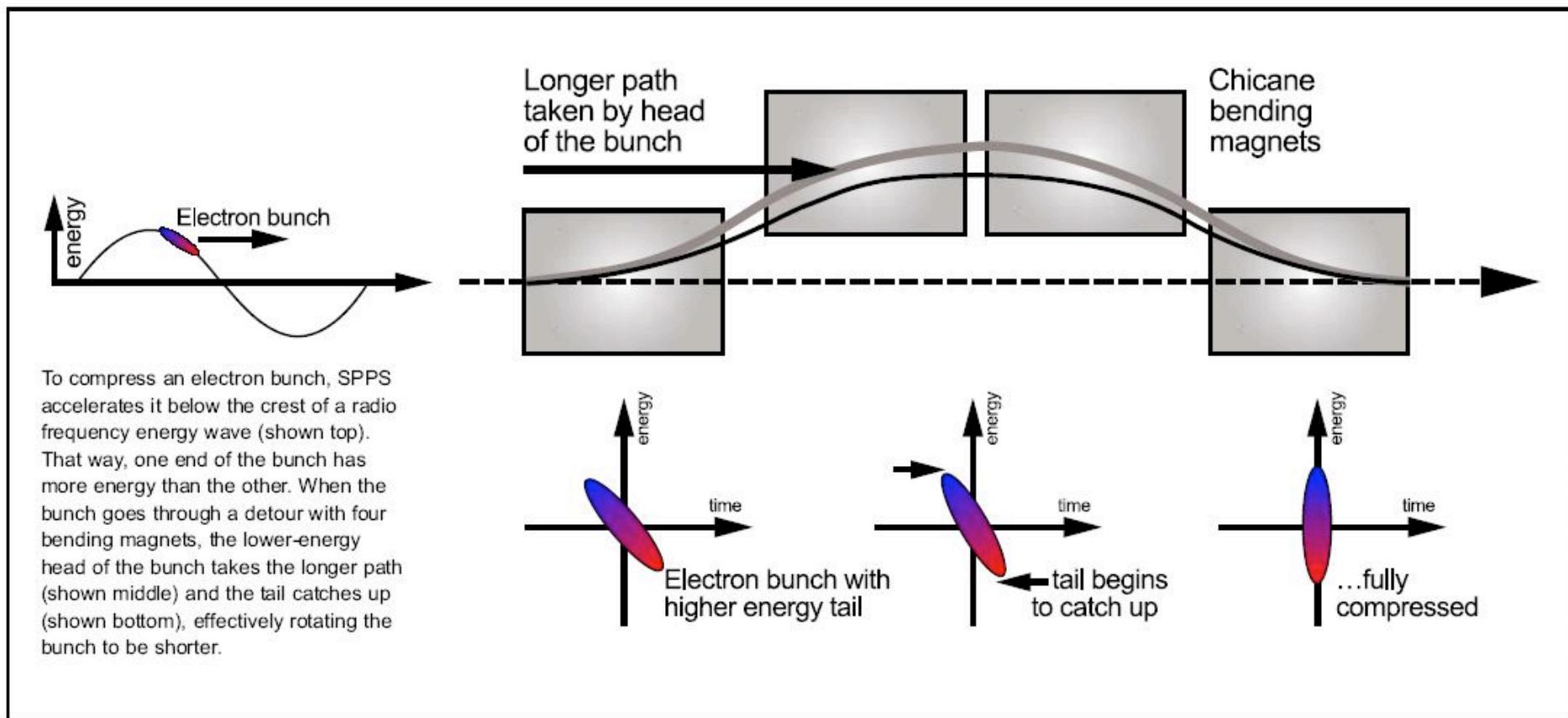
Outline

- Introduction to SPPS
 - Electron bunch compression
 - SPPS parameters
 - Streak camera measurements of timing jitter
- First experiments: Ultrafast structural changes in InSb
- Future experiments

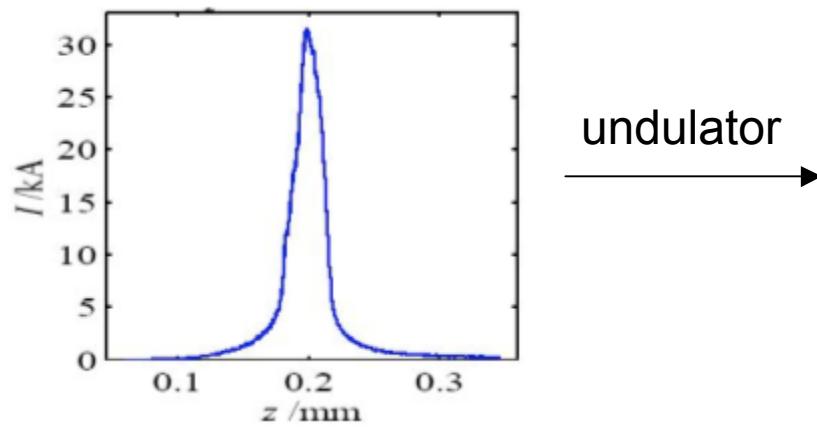
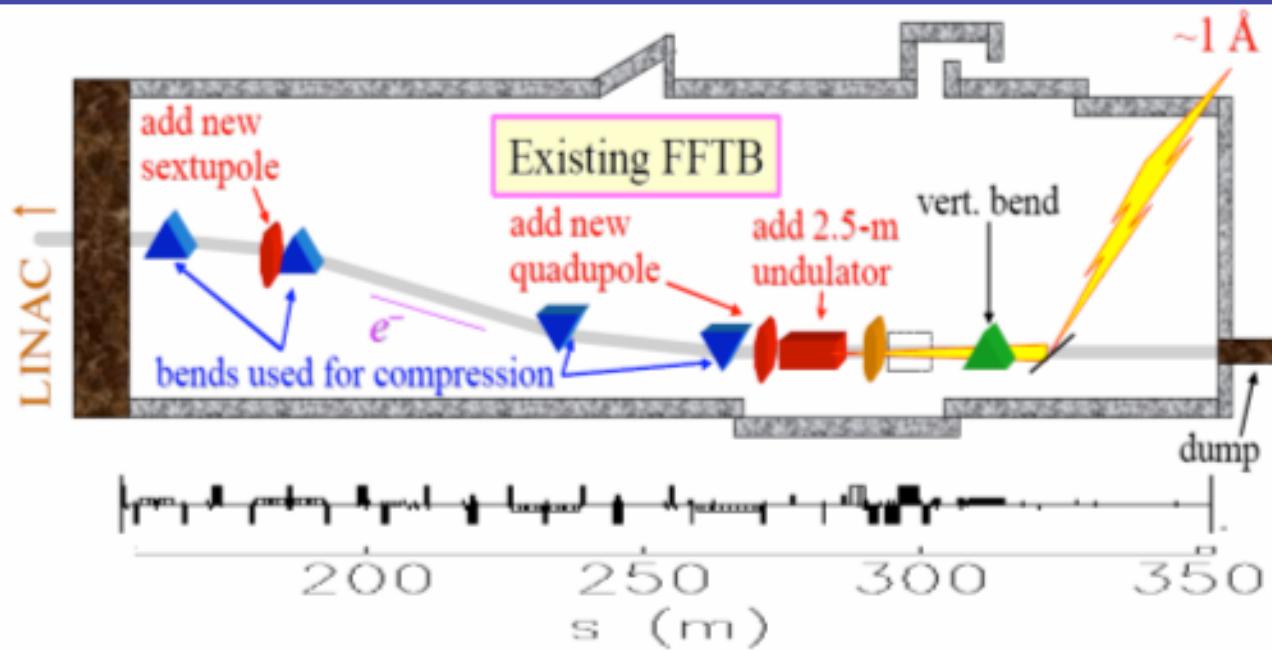
SPPS Characteristics



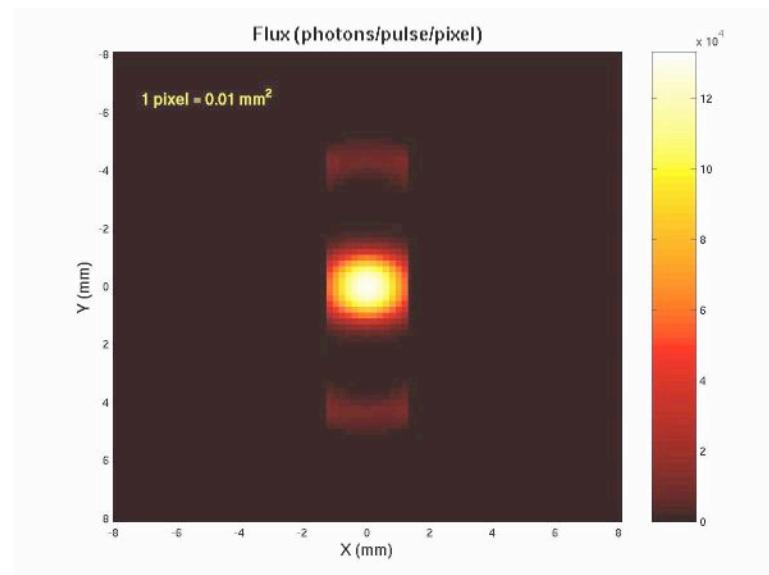
Electron Bunch Compression Scheme



Femtosecond X-rays at SPPS



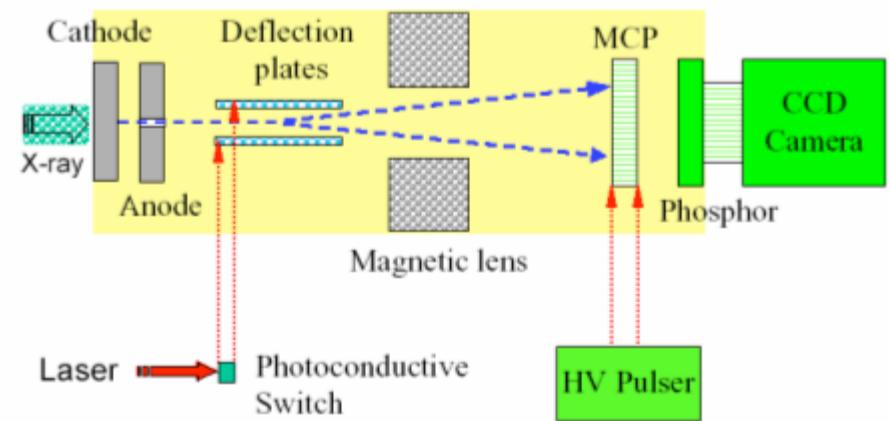
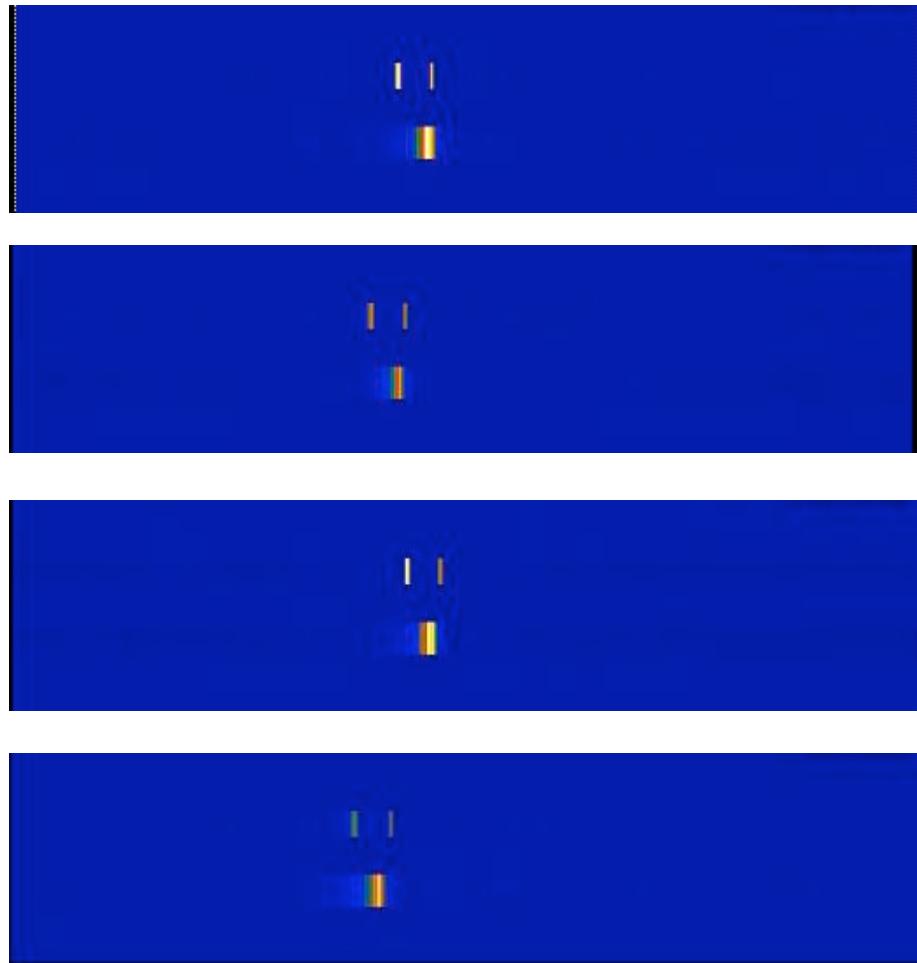
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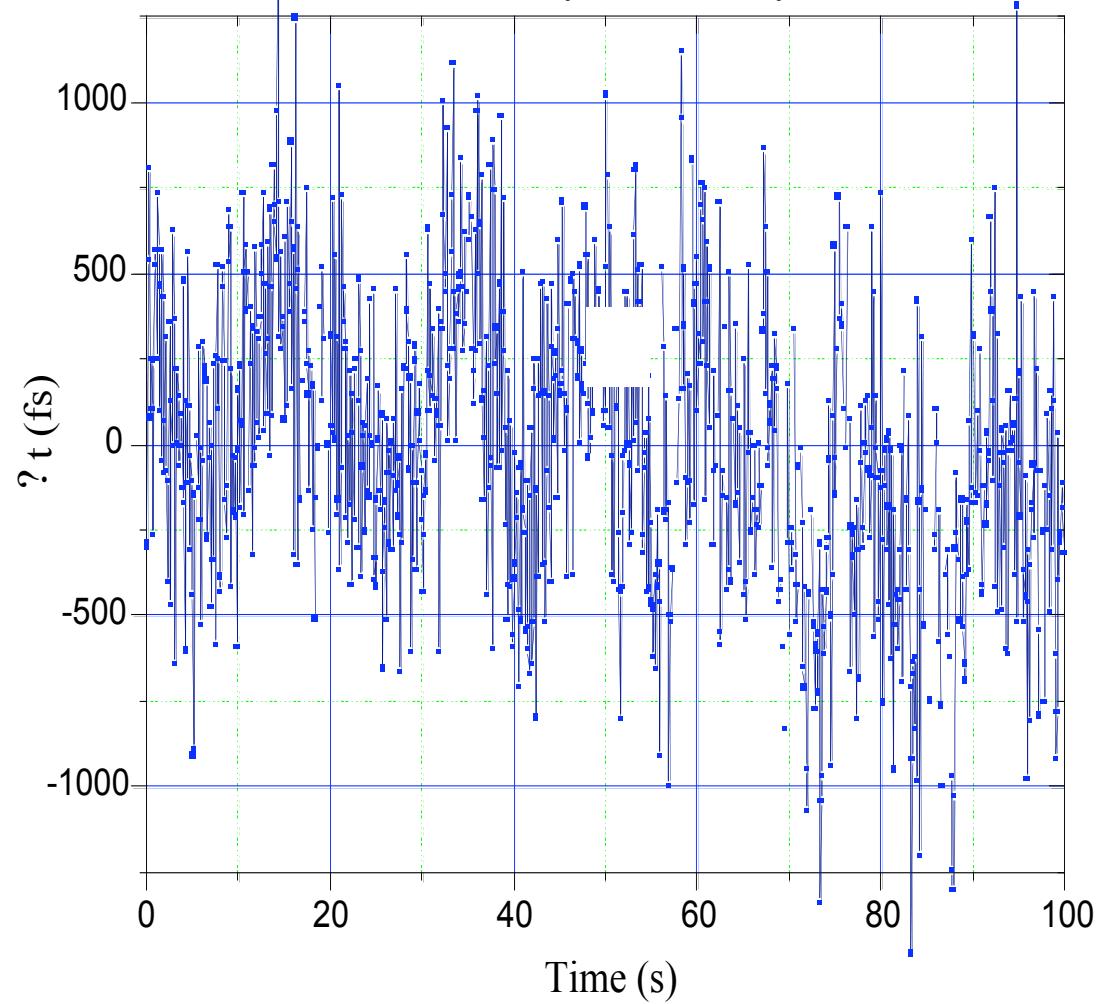
SPPS Parameters

- 2×10^7 photons/pulse/1.5% BW at 10 Hz
- Pulse duration: ~ 80 fs
- Tunable over 8-10 keV
- Synchronization of laser/x-rays ~ 1 ps
- ~ 2 mm spot size (unfocused)
- ~ 250 μm (Be lens) ($\sim 5 \times 10^6$ ph/pulse)
- <1 μm (KB) ($\sim 1 \times 10^6$ ph/pulse)

Streak Camera Timing Measurements



Jitter measured in the X-ray hutch at 10Hz for 100 seconds.
Laser vs X-rays: uncertainty $\pm 120\text{fs}$.



Ultrafast Melting Experiments in Semiconductors

- Previous experiments:

Rousse *et al.* *Nature* **410**, 65 (2001)

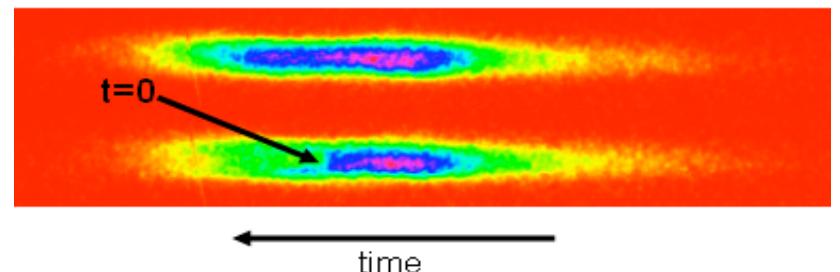
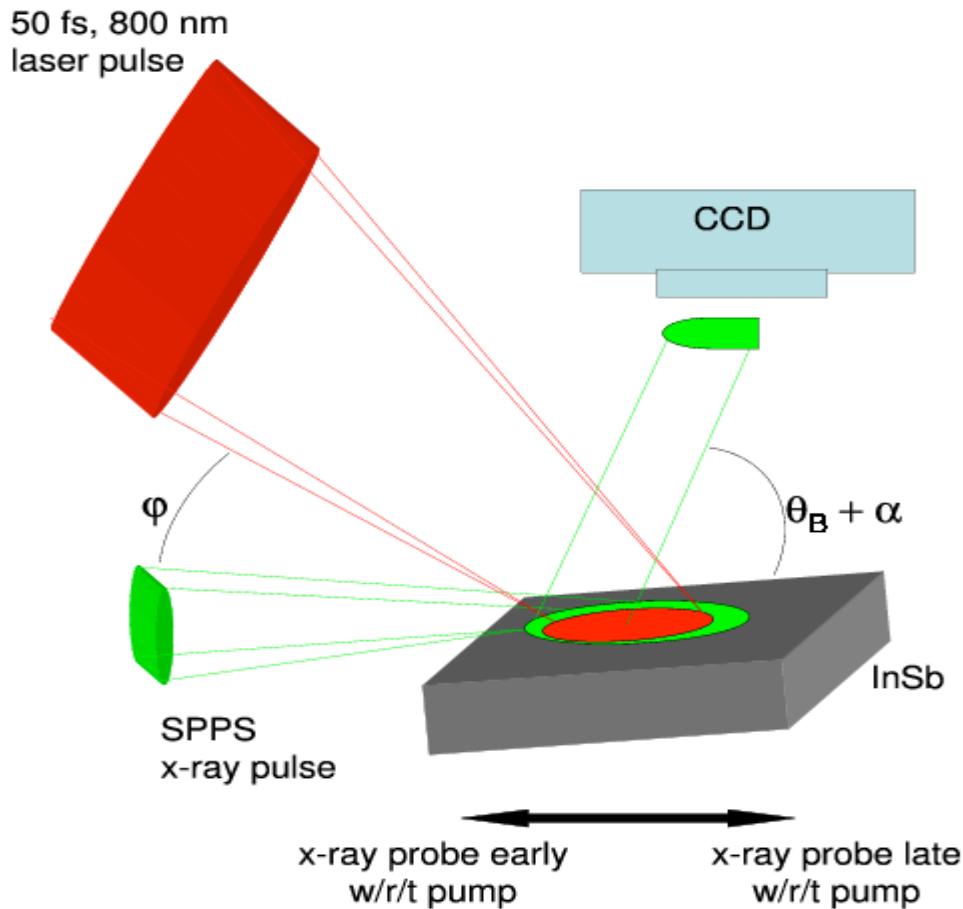
Sokolowski-Tinten *et al.* *PRL* **87**, 225702 (2001)

Siders *et al.* *Science* **286**, 1349 (1999)

Chin *et al.* *PRL* **83**, 336 (1999)

- Melting is an unsolved problem even under conditions of thermodynamic equilibrium
- Vibrational or shear instabilities?
- Surface effects
- Role of coherence in disordering phenomena

Crossed-beam topography

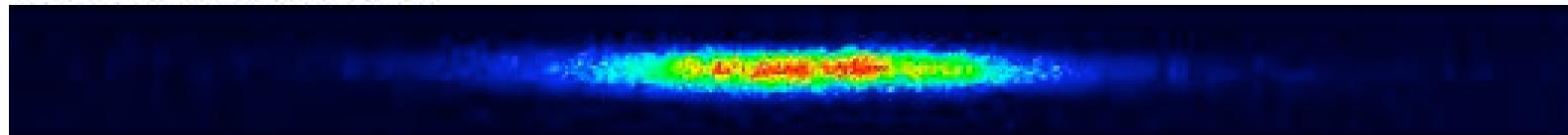


$$fs/pixel = \frac{\delta(\cos \theta_I - \cos(\theta_I + \phi))}{c \sin(\theta_B + \alpha)}$$

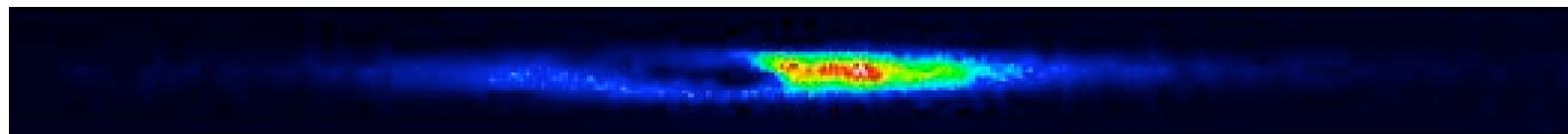
(For $\varphi = 24$ deg and x-rays grazing: ~ 18 fs/pixel)

Snapshots of surface dynamics

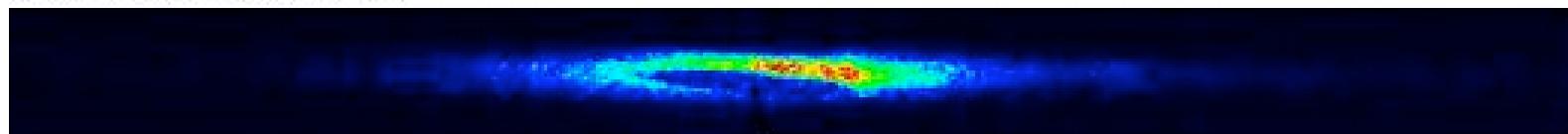
before laser illumination



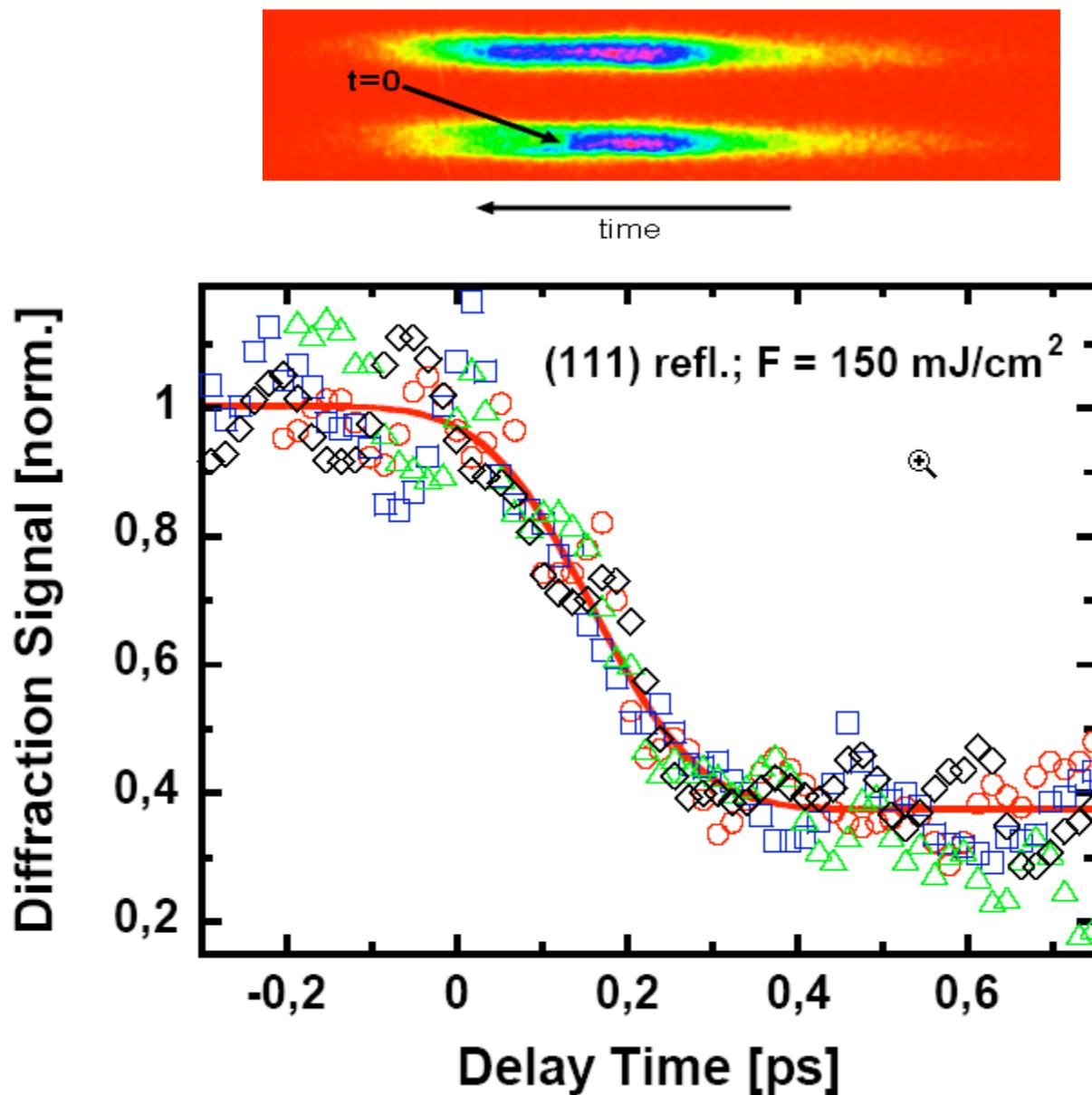
during laser illumination



after laser illumination



"damage" spot



Comparison to experiment and theory

- Previous experiments:

Rousse et al.: 350-600 fs in InSb

Sokolowski-Tinten et al.: ~300 fs in Ge thin films

Current measurements in InSb: ~200 fs

scaling prediction:
(Stampfli-Bennemann)

$$\tau \sim d^2 \sqrt{M}$$



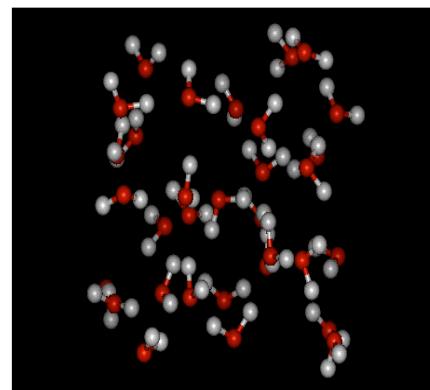
InSb: 350 fs (based on
prediction for Si)

- How does the time scale for disordering depend on
 - excitation conditions (fluence)
 - sample (isotope effect)
 - probe depth (time-resolved measurements near the critical angle)
 - Q-dependence?

Future Experiments

- Solid-Solid structural phase transitions (TTF-CA)/Coherent dynamics in solids

- Liquid State Experiments



- High Intensity X-ray Physics: X-ray pump/laser probe experiments

SPPS Collaboration

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